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Uniform Shelterwood Systems in the Sub-Boreal Spruce Zone: Update for Year 15 (Phase 2)

1 INTRODUCTION

For economic and biodiversity reasons, it is important to retain a range of tree species across timber supply areas. A trial testing a uniform shelterwood silvicultural system was initiated in the Sub-Boreal Spruce biogeoclimatic zone in the Central Cariboo Forest District (Williams Lake) in 1990 to develop harvesting strategies that would promote regeneration of Douglas-fir (*Pseudotsuga menziesii*) on sites where Douglas-fir had been the leading species in the mature stand. The traditional method of clearcutting, followed by planting, was not successful because of poor seedling performance due to the susceptibility of Douglas-fir seedlings to frost damage. Currently there are no stocking or free-growing standards for shelterwoods in this zone. Information is needed to support decision-making for shelterwood silvicultural systems, including species selection and harvesting methods.

The initial harvesting entry in 1991 focussed on removing 30% (preparatory cut) or 50% (regeneration cut) of the initial basal area. Early results from the first harvest entry in 1991 up to 1998 are reported by Burton et al. (2000) and Waterhouse (1999). In early 2001, a second harvesting entry was made into two of the original treatment units (30 m^2 and 40 m^2), further reducing the extant basal area by 50%. This produced a range of residual basal area (RBA) treatments: (1) 15 m^2 (second regeneration cut), (2) 20 m^2 (preparatory cut plus regeneration cut), (3) 30 m^2 (regeneration cut), (4) 40 m^2 (preparatory cut), and (5) 60 m^2 (no harvest), replicated on three sites. This extension note describes trial results for the 5-year period after the second harvest for seedfall, vegetation, natural regeneration, planted stock, tree fall, and microclimate.

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2 OBJECTIVES

The objectives have been refined for the second phase of this project to:

1. Evaluate the impact of various levels of basal area retention on the survival and growth of natural and planted regeneration. This information will result in recommendations to aid development of guidelines for shelterwood silvicultural systems, including species selection and harvesting methods in the Sub-Boreal Spruce zone.
2. Document the differences in vegetation development across the logging treatments. Understorey vegetation can strongly compete with tree regeneration for site resources, is important cattle and mule deer forage, and is a valuable component of wildlife habitat.
3. Assess climate conditions in the shelterwood treatments to help interpret regeneration response to different levels of basal area retention. Sufficient light is required to maximize tree growth; however, enough canopy must be left to reduce frost damage.
4. Refine silvicultural systems for mule deer winter range, by defining the relationship between snow depth and canopy closure.

3 METHODS

The trial is a randomized complete block design replicated on three sites: Beedy Creek (BEE), Gavin Lake (GLR), and UBC. Each block is 20–37 ha, and contains five 1.4-ha treatment units. Each treatment unit contains 15 subplots. Treatment units are surrounded by a harvested buffer (20 m^2 RBA). The trial blocks are in the Sub-Boreal Spruce dry warm biogeoclimatic subzone, Horsefly variant (SBSdw1), on mesic sites. At the time of harvesting, the stands were leading in Douglas-fir, with a lesser amount of lodgepole pine (*Pinus contorta* var. *latifolia*) and hybrid white spruce (*Picea glauca* x *engelmannii*). Data were also collected from three clearcuts (0 m^2 RBA), each close to one replication of residual basal area treatments. Removals for both entries were based on thinning from below (Figure 1). The final cut will be completed on all units in 2011, depending on regeneration density and size.

4 RESULTS

4.1 Seedfall

After the second entry in 2001, seedfall was collected annually on the 20 m^2 and 60 m^2 (unharvested) treatments. Pine and subalpine fir (*Abies lasiocarpa*) seed made up less than 6% of the total viable seed crop in any 1 year. In most years, Douglas-fir dominated the seed crop (49–98%). Spruce trees make up less than 5% of the overstorey, but in good years, such as 2003, they are prolific seed producers (105 000 viable seeds/ha in the 20 m^2 unit and 233 000 in the 60 m^2 unit). The largest Douglas-fir seed crop in the last 3 years occurred in 2001 (570 000 viable seeds/ha averaged across treatments and sites), although substantial viable seed was produced in 2002 (115 000 seeds/ha) and 2003 (163 000 seeds/ha) as well (Figure 2). Viability of the seed crop varied from year to year (42% in 2001, 24% in 2002, 33% in 2003, and 8% in 2004) and was generally higher in the larger seed crops.

The 2001 seed crop was much larger in the 20 m^2 units than the 60 m^2 units on all three sites, and there was a similar pattern in 2003. The 2002 seed crop results were variable, and the seed crop in 2004 failed. If seed production were divided by stem density, for an estimate of seed production per tree, then seed production would be consistently higher in the 20 m^2 treatments. The large differences in the 2001 seed crop may have been caused partially by the sudden increased exposure to light and wind due to harvesting the previous winter. Greater productivity could also be due to the increased resources per residual tree after harvesting.

4.2 Vegetation

Some individual species and the extent of vegetation cover by layer can modify the performance of Douglas-fir regeneration. Also, certain species have high forage value

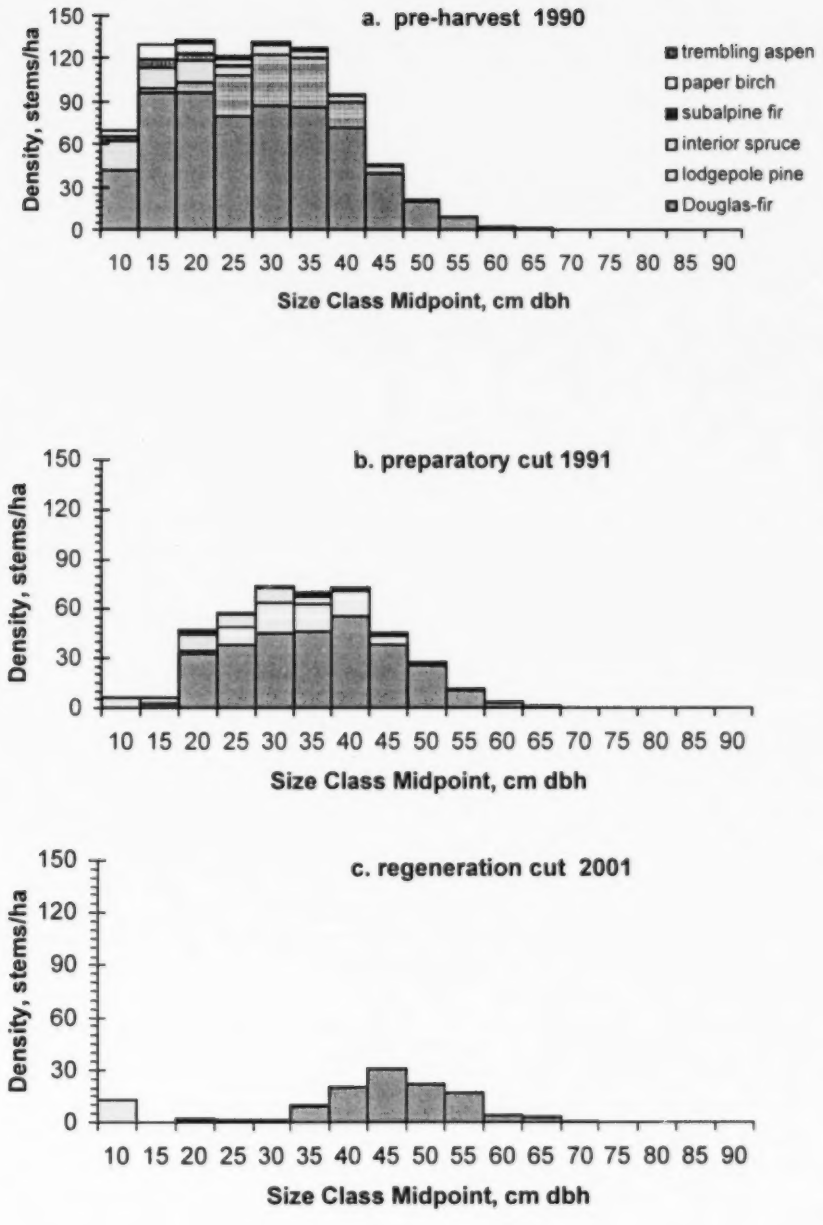

FIGURE 1 Average density of stems (>7.5 cm dbh) in the (a) pre-harvest, (b) preparatory cut (1991), and (c) regeneration cut (2001) treatments (n=3 sites).

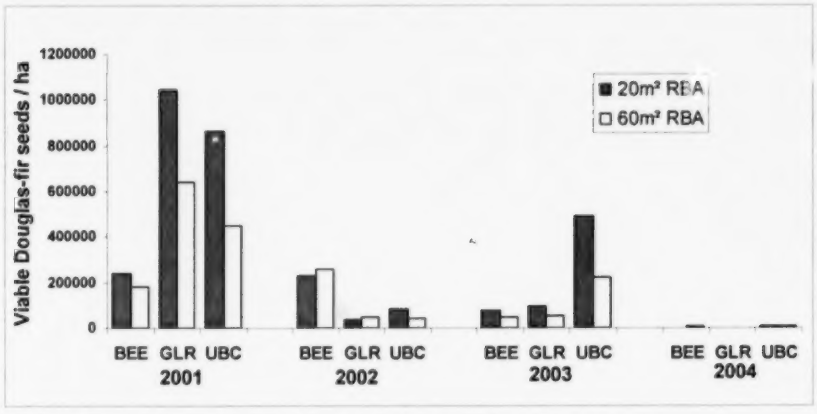

FIGURE 2 Mean annual crop of viable Douglas-fir seed by site and treatment.

for mule deer or cattle. From 2000 to 2004, percent cover data were collected from 3.99-m radius subplots nested in the 15 m^2, 20 m^2, 30 m^2, 40 m^2, and 60 m^2 treatments. A total of 119 vascular plant species were identified, of which 25 occurred at more than 1% cover. Analysis of variance, based on the 2004 data, found no significant (α=.05) differences among treatments for the shrub layers (B1 and B2) (35–56%), or the herb layer (C) (34–56%); however, the percent cover of the moss and lichen layer (D) was significantly affected by residual basal area (p=0.009). There was about 50% less moss and lichen in the 15 m^2, 20 m^2, and 30 m^2 treatments than in the 40 m^2 or 60 m^2 treatments (56–59% cover).

Species-specific differences were also detected. Twinflower (*Linnaea borealis*) (p=0.04), hybrid white spruce (p= 0.09), and Douglas-fir (p=0.03) all showed significantly higher cover in the 15 m^2 and 20 m^2 treatments. Douglas-fir averaged 15–21% in the 20 m^2 and 15 m^2 treatments, compared to 13% in the 30 m^2 treatments and 6% in the higher residual basal area treatments. Spruce cover was 10% in the 15 m^2 treatments, but 4% or lower in the others. In 2001, subalpine fir was slashed in the 15 m^2, 20 m^2, 30 m^2, and 40 m^2 treatments, reducing the cover from 9–18% to less than 1% in the harvested treatments, while it remained at 5% in the unharvested treatment (60 m^2) (p=0.06). Mule deer diets from winter ranges in the area contain about 13% subalpine fir (Waterhouse et al. 1994), so the implications of widespread slashing should be a management consideration. Four years after the second harvest (and slashing treatment), Douglas-fir regeneration responded positively to the increased resources, while the herb and shrub layers, and the cover of the majority of plant species, remained similar among treatments. Common species such as saskatoon (*Amelanchier alnifolia*), prickly rose (*Rosa acicularis*), common snowberry (*Symphoricarpos albus*), pinegrass (*Calamagrostis rubescens*), purple peavine (*Lathyrus nevadensis*), and rough-leaved ricegrass (*Oryzopsis asperifolia*), eaten by cattle in the summer, did not vary significantly among treatments.

4.3 Natural Regeneration

4.3.1 Density The density of natural regeneration was counted by species and size class in 2004. This was the fourth year following the second harvest for the 15 m^2 and 20 m^2 units and fourteenth year post–first harvest for the 30 m^2 and 40 m^2 units. Although there are a number of species on the sites, Douglas-fir regeneration was the most abundant (at 90%) in all size classes. Other species included aspen (*Populus tremuloides*), birch (*Betula papyrifera*), cottonwood (*Populus balsamifera*),

subalpine fir, western redcedar (*Thuja plicata*), lodgepole pine, and spruce. The density of small Douglas-fir saplings (>100 cm tall and <7.5 cm dbh) was significantly ($p=0.0004$) higher in the 15 m^2, 20 m^2, and 30 m^2 treatments (3100–3800 stems/ha), than in the 40 m^2 and 60 m^2 treatments (800–1100 stems/ha). The other four size classes of trees — germinants, small (<10 cm tall), medium (10–30 cm tall), and large (31–100 cm tall) — did not differ significantly ($\alpha=0.05$) among treatments. At present, the regeneration density of Douglas-fir (>10 cm tall) in the original regeneration cut treatments (15 m^2 and 30 m^2) on all sites (6200–40 000 stems/ha) will meet regeneration objectives. This is less likely in the other treatments due to low densities on some sites and poorer quality of the regeneration, particularly on the preparatory and no-harvest treatments. It is expected that the regeneration density and quality will increase over time in the 20 m^2 treatment, particularly at the UBC site (currently at 3200 stems/ha).

There continues to be a great deal of variability between the sites, with the highest density of Douglas-fir regeneration (all size classes) occurring on the BEE site (35 000–56 000 stems/ha), compared to the GLR site (3 000–23 000 stems/ha), and the UBC site (1500–9600 stems/ha). On the UBC and GLR sites there was a pattern of density associated with treatment (Figures 3 and 4). The least regeneration occurred in the 60 m^2 treatments (1500–3000 stems/ha), and the 15 m^2 and the 30 m^2 units had the most (6 000–25 000 stems/ha). The 20 m^2 treatments may have less because the seed cut was applied only in 2001, and before that the residual basal area was quite high (40 m^2), impeding regeneration. At Beedy Creek the regeneration density was high in all treatments, but particularly in the 40 m^2 and 60 m^2 treatment units (Figure 5). The differing patterns among sites may be the ongoing consequence of the huge 1993 seed crop. It was double (~3 000 000 Douglas-fir seeds/ha) at the BEE site compared to the GLR and UBC sites (Burton et al. 2000). The many small seedlings (<10 cm tall), which established in the 40 m^2 and 60 m^2 treatments in 1994, were still present in 2004 (~30 000 stems/ha) and they have not advanced to the larger size classes due to inadequate light and other resources.

4.3.2 Growth of natural regeneration A retrospective growth study was completed in 2005. Trees in two size classes (30–100 cm tall; > 100 cm tall and < 4 cm dbh) that exhibited the

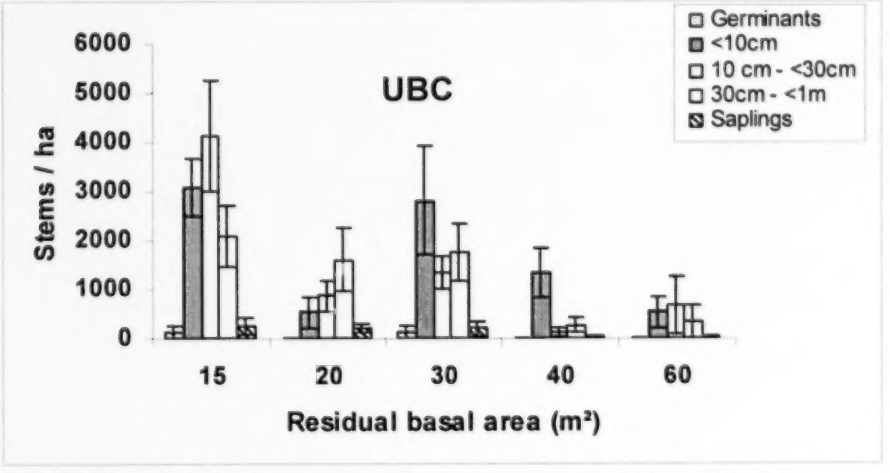

FIGURE 3 Mean and standard error for Douglas-fir regeneration density at the UBC site.

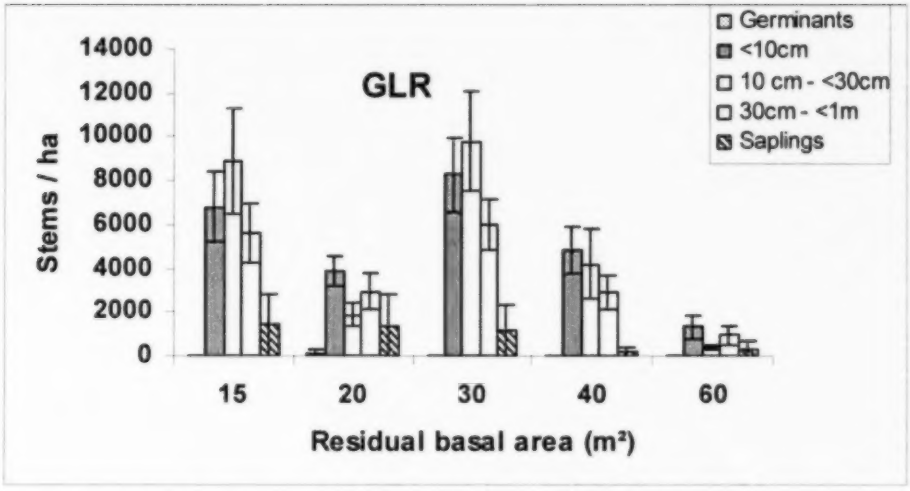

FIGURE 4 Mean and standard error for Douglas-fir regeneration density at the GLR site.

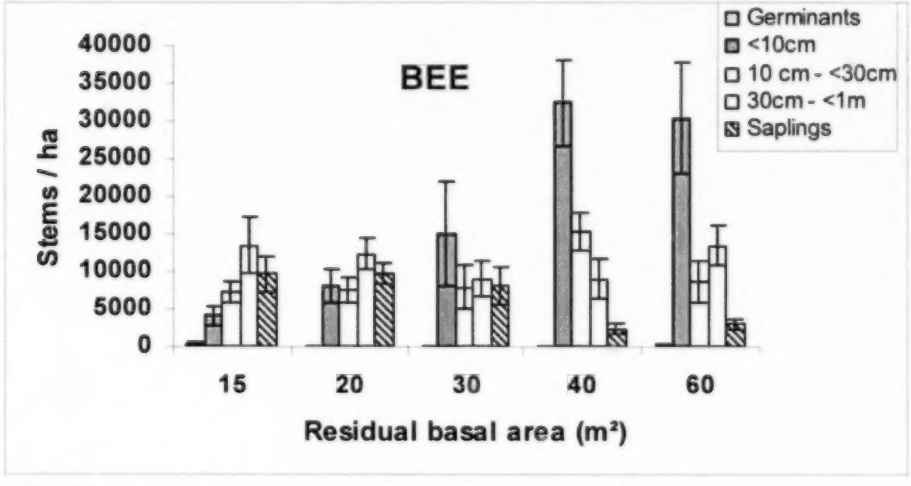

FIGURE 5 Mean and standard error for Douglas-fir regeneration density at the BEE site.

best growth and condition were selected from each treatment unit, and annual height increments from 2000 to 2005 and diameters were measured. There were significant differences in height growth (2000–2005) for trees over 100 cm tall ($p=0.02$), 2004–2005 leader ($p=0.01$), and diameter ($p=0.007$). For all variables, the trees in the 15 m^2 units were bigger than those in the 40 m^2 or 60 m^2 units. Differences in height increments were strongest in 2005, with trees in the 15 m^2 unit growing the most (Figure 6). The height and diameter of the smaller trees (<100 cm) did not differ significantly among treatments.

4.4 Planted Stock

Although shelterwood systems are designed to encourage natural regeneration, seedlings

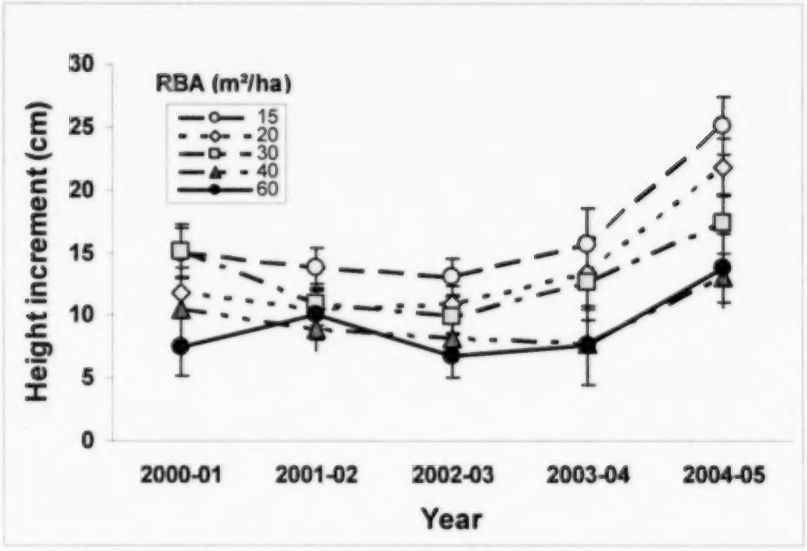

FIGURE 6 Mean and standard error of annual height growth of Douglas-fir regeneration (>100 cm tall and <4 cm dbh) by treatment.

were planted in the trial to obtain a faster and more consistent response to the growing conditions created by the harvesting treatments. The first planting was in spring 1994, 3 years after the initial harvest, and the second planting was in spring 2001, immediately after the second entry.

In 1994, 100 Douglas-fir seedlings were planted into each of the 60 m^2, 40 m^2, and 30 m^2 treatment units at each site. Seedlings were also planted in two adjacent clearcuts. After 10 years, survival was 80% in the clearcuts and 30 m^2 units, and 70% in the 40 m^2 units, but only 48% in the 60 m^2 units. Total height growth and diameter growth were significantly ($p<0.05$) greater in the 30 m^2 treatment compared to the 40 m^2 and 60 m^2 treatments (Figure 7). Leader growth did not vary significantly ($p=0.07$). Growth was much faster in the clearcuts by year 10, but statistical comparisons were not possible because clearcuts were not part of the original study design. Damage to the trees in the clearcuts was initially high from frost and cattle trampling, but vigour and form improved as the seedlings grew through the frost layer. This was probably aided by the regenerating lodgepole pine trees that grew tall enough (3–4 m) to provide some shelter. The strong differences in the seedling growth response emphasize the need to reduce the basal area in the stand substantially to provide enough light and resources to the regeneration layer, while providing frost protection.

In spring 2001, after the second harvest, 150 Douglas-fir seedlings were planted in each treatment unit and in three nearby clearcuts. Fifth-year survival was 55–64% in the 0–40 m^2 units, and somewhat lower in the 60 m^2 units (38%). There were strong differences between sites, with BEE having the highest survival across all treatments (64–89%), and UBC the lowest (35–48% in all treatments except 60 m^2, where it dropped to 15%). At UBC, high mortality resulted from a combination of treatment effect, residual damage from salvage of wind throw, and incidental trampling by cattle during grazing. At GLR, survival ranged from 55 to 63% in all treatments except the 60 m^2, where it dropped to 27%. Fifth-year height growth was not significantly different among treatments

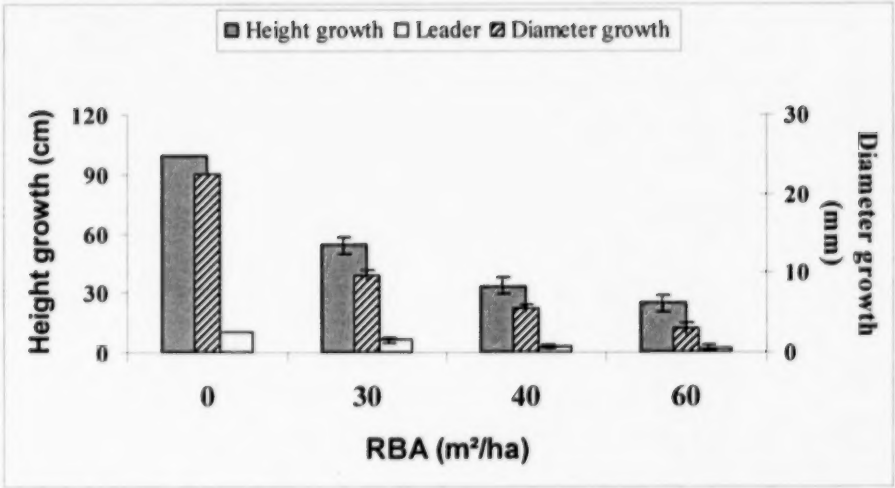

FIGURE 7 Mean and standard error of tenth-year height, leader, and ground-level diameter growth of planted Douglas-fir for the 30 m^2, 40 m^2, and 60 m^2 treatments. Mean growth in the clearcuts is for background information only.

(p=0.06), although seedlings were taller in the 15 m^2 and 20 m^2 treatments. Leader length in 2005 was significantly different between treatments (p=0.004). Leaders were especially large in the clearcuts compared to the 40 m^2 and 60 m^2 treatments. Diameter growth was significantly different among treatments (p=0.0001), and greatly increased with reduced residual basal area (Figure 8).

4.5 Tree Fall

After the second entry (from 2001 to 2005), a total of 131 trees fell in the strip transects set up in all treatments and sites. Of the total, 83 trees fell at UBC, 34 at GLR, and 14 at BEE. The direction of fall indicated wind prevailing from the east or north. Of the total fallen trees, 82% were Douglas-fir, with a smaller component of spruce (9%), pine (7%), and aspen (2%). Most of the trees were co-dominant (79%) and alive (83%) when they fell. The majority (63%) of trees fell when the entire root plate pulled out of the ground. This is typically caused by storms on sites with shallow, wet soils.

There were no consistent differences in the rate of tree fall among treatments in the first post-harvest period (1991–2000); however, this changed after the second harvest. The highest rates of annual tree fall were in the 15 m^2 and 20 m^2 treatments (5.3–7.3% of standing trees) compared to the 30 m^2 (1.8%), 40 m^2 (0.7%), and 60 m^2 (2.0%) treatments. Rates of tree loss were extremely high on the UBC site (12.7% in 15 m^2 and 21.2% in 20 m^2 treatments) compared to the same treatments on the GLR site (3.2% and 0%, respectively) and the BEE site (0% and 0.7%, respectively) (Figures 9 and 10). The UBC site is flatter and the soil is moister than at the other sites. The trees on this site have several features that make them susceptible to wind throw: shallow, flat root plates, large height-to-diameter ratios, and large crowns. An adjacent block was also harvested at the same time and may have allowed increased wind flow through the stand from the east. Most of the wind throw on the UBC site was caused by powerful windstorms that occurred once or twice a year from late October to early January.

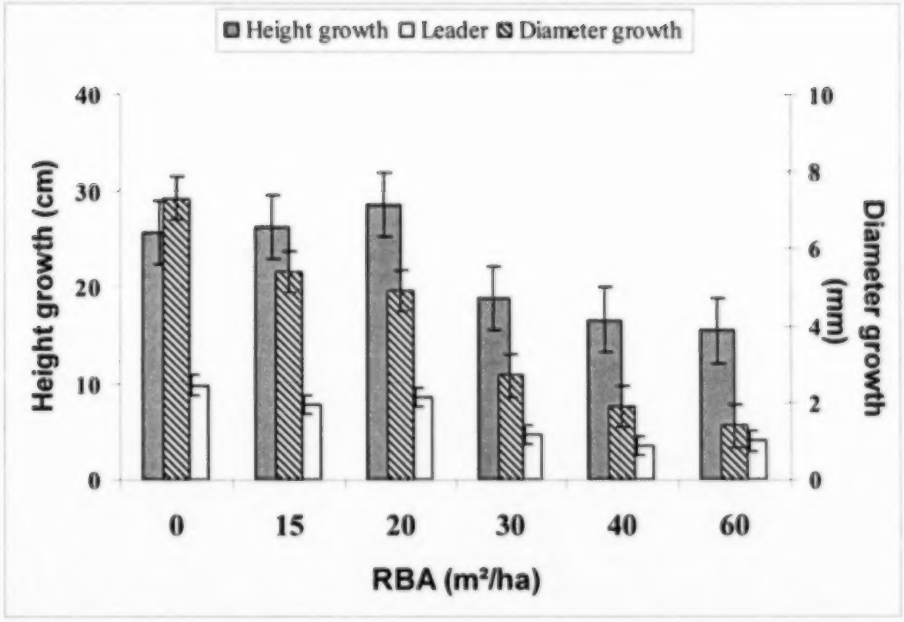

FIGURE 8 Mean and standard error of fifth-year height, leader, and ground-level diameter growth of planted Douglas-fir.

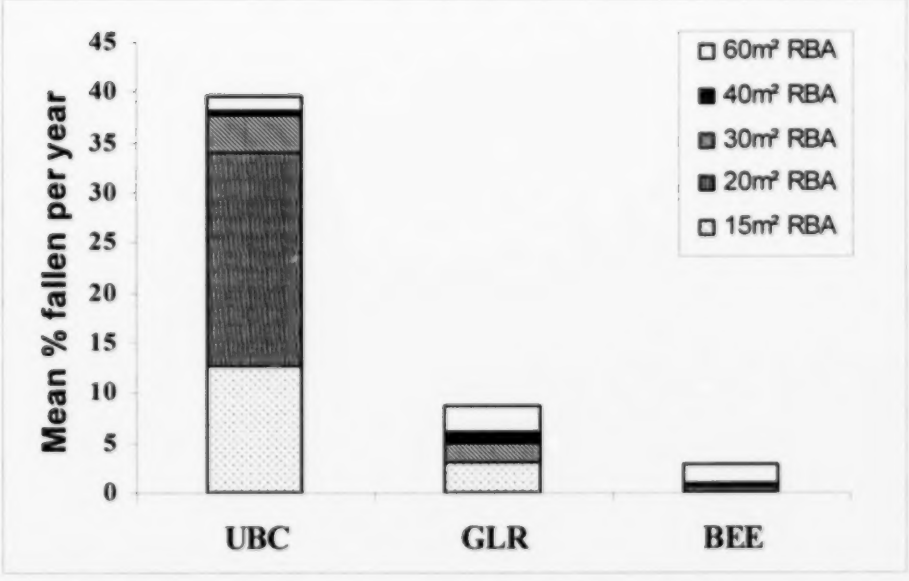

FIGURE. 9 Mean annual tree fall as a percentage of standing trees (n=4 years).

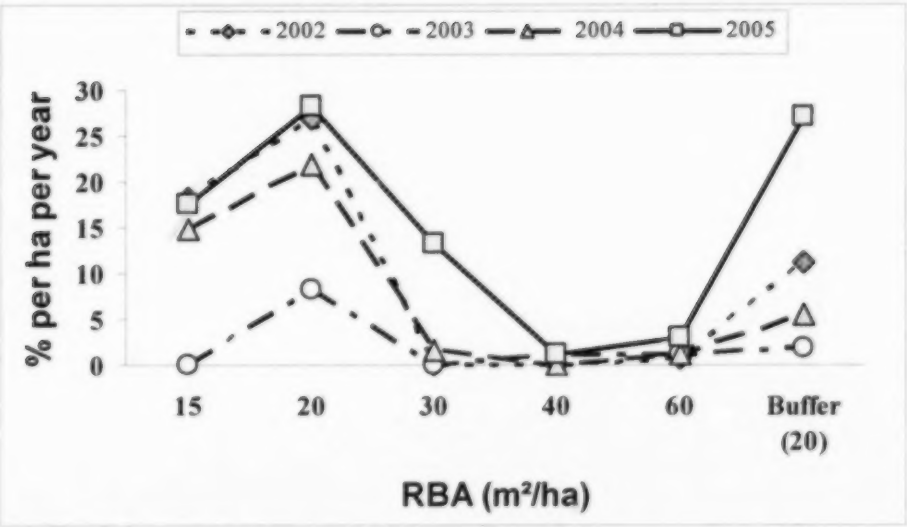

FIGURE 10 Annual rate of tree fall by treatment at the UBC site.

4.6 Microclimate and Snow Interception

Five stations were installed in 2001: one in each 20 m^2 treatment, one in the 0 m^2 treatment at GLR, and one in the 15 m^2 treatment at GLR). The residual forest cover has modified the stand microclimate compared to a clearcut, and the degree of modification increased with basal area retention. Since harvesting, the GLR clearcut had the longest duration of sub-freezing temperatures, lowest extreme minimum air temperatures, and the most frosts. For example, in 2004 in the clearcut there were 12 growing-season frosts, with two being severe (< -4° C), while under all shelterwood treatments there were only four to six frost events, and no minimum temperatures less than -4° C during the growing season. There were also differences among the forested RBA treatments. Minimum air temperature was typically lower at the GLR 15 m^2 (sometimes more than 1° C lower) than in the 20 m^2 unit. In a few cases this represented the difference between having frost at the GLR 15 m^2 and no frost at the GLR 20 m^2 site. The seasonal mean minimum air temperature at GLR 15 m^2 was 0.5° C lower than at GLR 20 m^2, while the extreme minimum was 1.2° C lower.

Apparent snow interception was measured at the subplots in all treatment units. Canopy density was measured at the same points using hemispherical photographs at an angle of 50° from vertical. Regression analysis found a strong positive relationship between the average amount of canopy per treatment unit and degree of snow interception (r^2=.81, n=15).

5 SUMMARY

The uniform shelterwood silvicultural systems trial in a Douglas-fir–leading forest produced the following results:

1. The Douglas-fir seed crop, moderately large in most years, is reliable to initiate natural regeneration.
2. Application of the initial regeneration cut in 1991 resulted in sufficient densities of natural regeneration to meet regeneration objectives. This is not the case in preparatory and no-harvest treatments, due to the variability in density and the poorer quality of the regeneration.

3. Data from the planted stock and natural regeneration trials suggest that the rate of growth increased as a result of the reduction in RBA from 30 m^2 to 15 m^2 and from 40 m^2 to 20 m^2. Seedling growth was lowest in the 40 m^2 and the no-harvest (60 m^2) treatments.
4. Frost damage to the planted stock was very low in all treatments, including the clearcuts since 2001. The frost events recorded at the climate stations were not severe enough to cause permanent damage.
5. Moss and lichen were reduced by 50% where the RBA was 30 m^2 or less; however, no differences between treatments were found for cover of the other vegetation layers. The percent cover of Douglas-fir, spruce, subalpine fir, and twinflower all increased in response to lowering the residual basal area.
6. Strong wind events, in combination with flat, moist site conditions, have resulted in high rates of tree fall in the 15 m^2 and 20 m^2 units on the UBC site. This demonstrates that there are wind-related limitations to where a uniform cutting system at low residual basal areas may be applied.
7. The strong relationship between canopy density and snow depth (snow interception capacity) will be used to develop stand and silvicultural system prescriptions for deep-snowpack mule deer winter ranges in the Sub-Boreal Spruce zone in the Cariboo region.

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